DETAIL Practice

Building with Steel

Details
Principles
Examples

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Edition Detail

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Contents

Introduction

Alexander Reichel

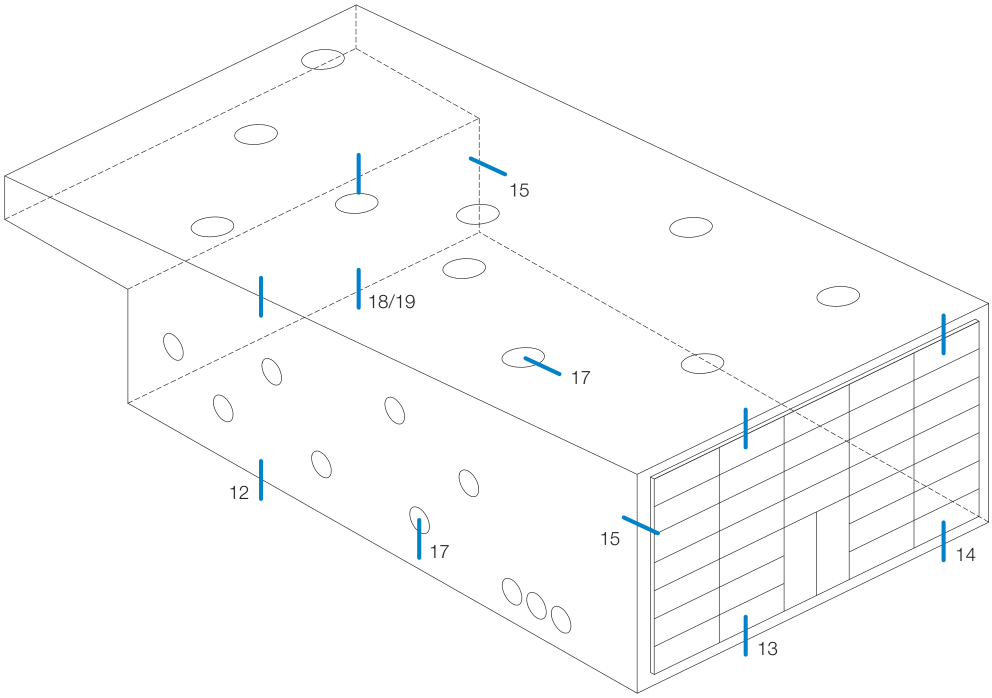
The book is divided into four main sections supplemented by case studies, tables and an index. The order of the chapters extends from examples of complex applications through the jointing and arrangement of the loadbearing structure, the design of structures and, finally, individual products and semi-finished articles made from steel. To start with, two typical structural steelwork projects are presented as examples together with their specific details. Construction and architecture, loadbearing structure and enclosing envelope, are brought together in the drawings, corresponding to the typical working details of architects.

The second part of the book deals with the principles of structural steelwork design and the stability of the various construction elements. This is followed by the fundamentals behind the design of the connections between individual construction elements, which are supplemented by case studies.

A systematic selection of the most important steel sections and semi-finished products rounds off the overview of this subject. This section of the book is complemented by brief explanations of the technical parameters of corrosion and fire protection, thermal and acoustic insulation. Finally, this introduction to structural steelwork includes case studies of steel structures, which demonstrate the diverse range of potential applications, plus tables and data that furnish the reader with a rapid, clear understanding of this subject.

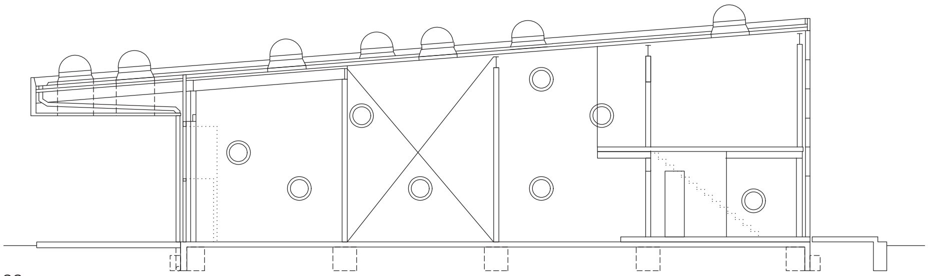
The selection of structures and surface finishes, the delicate design and the profiling of the loadbearing structure, also the layout and precision of the connections, characterise structural steelwork and result in the architectural and sensual appeal of steel structures. The properties of the material initially permit all design freedoms, something that is proved by the diverse architecture of the different structures. Owing to the rapidity of erection, the long economic spans and the relative ease and flexibility with which steel structures can be built, steel is an industrial building material. However, the growth in the number of refurbishment projects and the changing demands regarding interior design open up further application options for structural steelwork.

The combined planning discipline of architects and engineers will thus enable the qualities of this material to come to the fore and steer the diversity of the constructions and semi-finished products in creative directions.



Overview of details
scale 1:20

12 Section through metal facade
Corner and base of portal frame
13 Section through mezzanine floor
14 Section through glass facade
15 Horizontal section through metal and glass facades
16 Composite floor, window strip
17 Rooflight
18 Overhead door
19 Folding door



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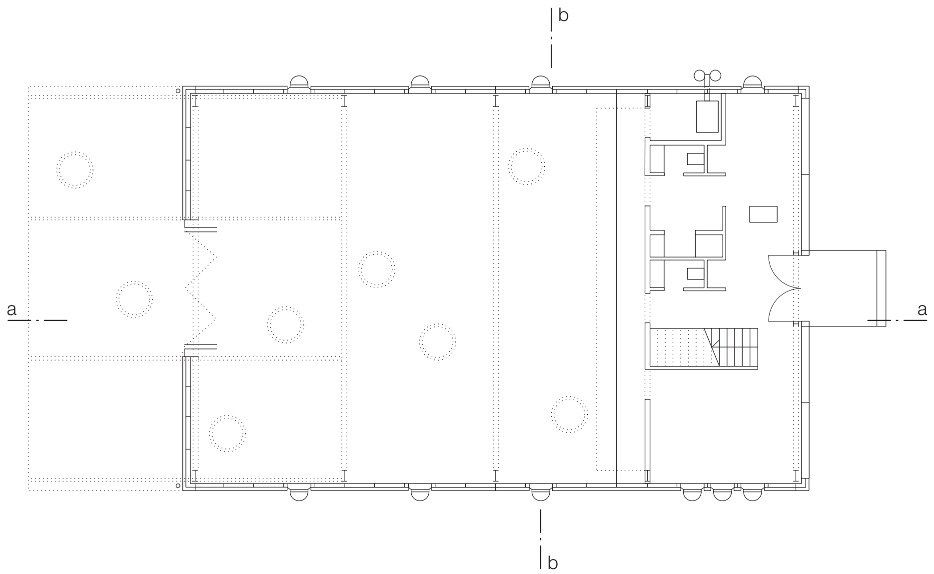

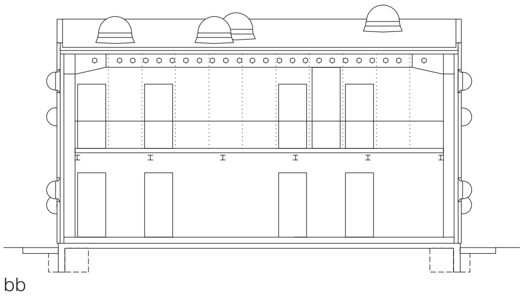

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The demands placed on speed of fabrication and erection, on flexible usage and conversion, plus economic considerations, frequently result in steel being chosen for the loadbearing structures of wide-span industrial sheds.

Example A therefore shows a single-storey shed which could be used as a workshop, warehouse, retail outlet or production plant. The arrangement of the plot corresponds to the layout often found on industrial estates, with circulation around the building possible as well as entrance and exit. The building itself is designed as a compact enclosing envelope offering various types of interior qualities: at the front, reception and display areas plus staff facilities, including changing rooms, and above these further offices which permit direct communication with the main part of the building behind. Between these and the covered loading/unloading area at the rear of the building lie the large open bays devoid of disturbing intervening columns.
Steel permits virtually any shape and size of single-storey shed to be built. Such sheds can be classified according to number of bays, type of roof, the internal structures, overhead cranes, shelving systems, etc. The shed shown here is a single-bay standard structure without overhead crane but including a mezzanine floor for the offices.
The grid of the loadbearing construction in this example is 5 m, a common dimension for such buildings. Such grids have also proved economic, for the sizes of interior furnishings and fittings. A balance has to be found between the depths of floors and beams and the unsupported spans of the sheet metal roof covering, as well as erection options.
In contrast to the offices, the heating to the main part of the shed is minimal (approx. 16°C) – customary these days. The floor area of the open part of the shed is an important criterion because it is this area that determines the applicability of the various standards. For example, in the Industrial Buildings Directive and DIN 18230 the fire protection requirements for sheds up to 200 m^2 are less stringent.

The examples show, primarily, the interaction of loadbearing structure, interior fittings, envelope and architectural ideas. The aim is to explain how a building with an appealing external appearance is developed from a steel loadbearing structure using the jointing logic and lucid geometry of structural steelwork.

The design of a steel structure is essentially determined by two main features: the loadbearing elements and the external envelope. A steel structure is resolved into individual loadbearing members and therefore is usually designed as a frame.

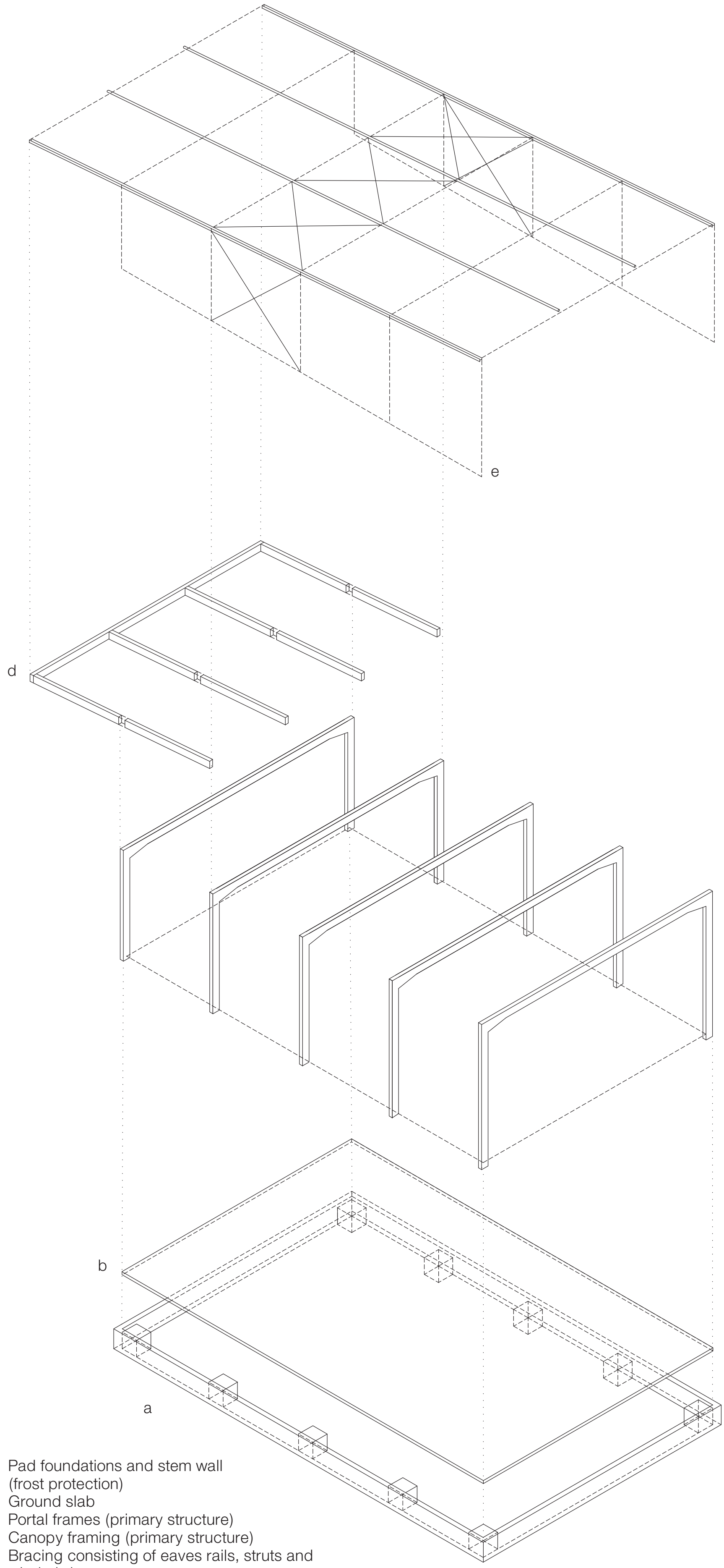
The loadbearing structure of a building is made up of the foundations, columns, beams, frames, arches or cables forming the loadbearing framework, plus the necessary bracing and stabilising elements.

A loadbearing structure must be stable in at least three directions. The vertical loads to be carried include self-weight, dead, wind, snow and imposed loads. The horizontal loads consist of wind, crane and impact loads. In industrial sheds the type of use means that the risk of impact (by vehicles or cranes) is considerably higher than in conventional buildings. Protection against impact can take the form of using heavier members for the loadbearing construction itself, or the provision of separate barriers.

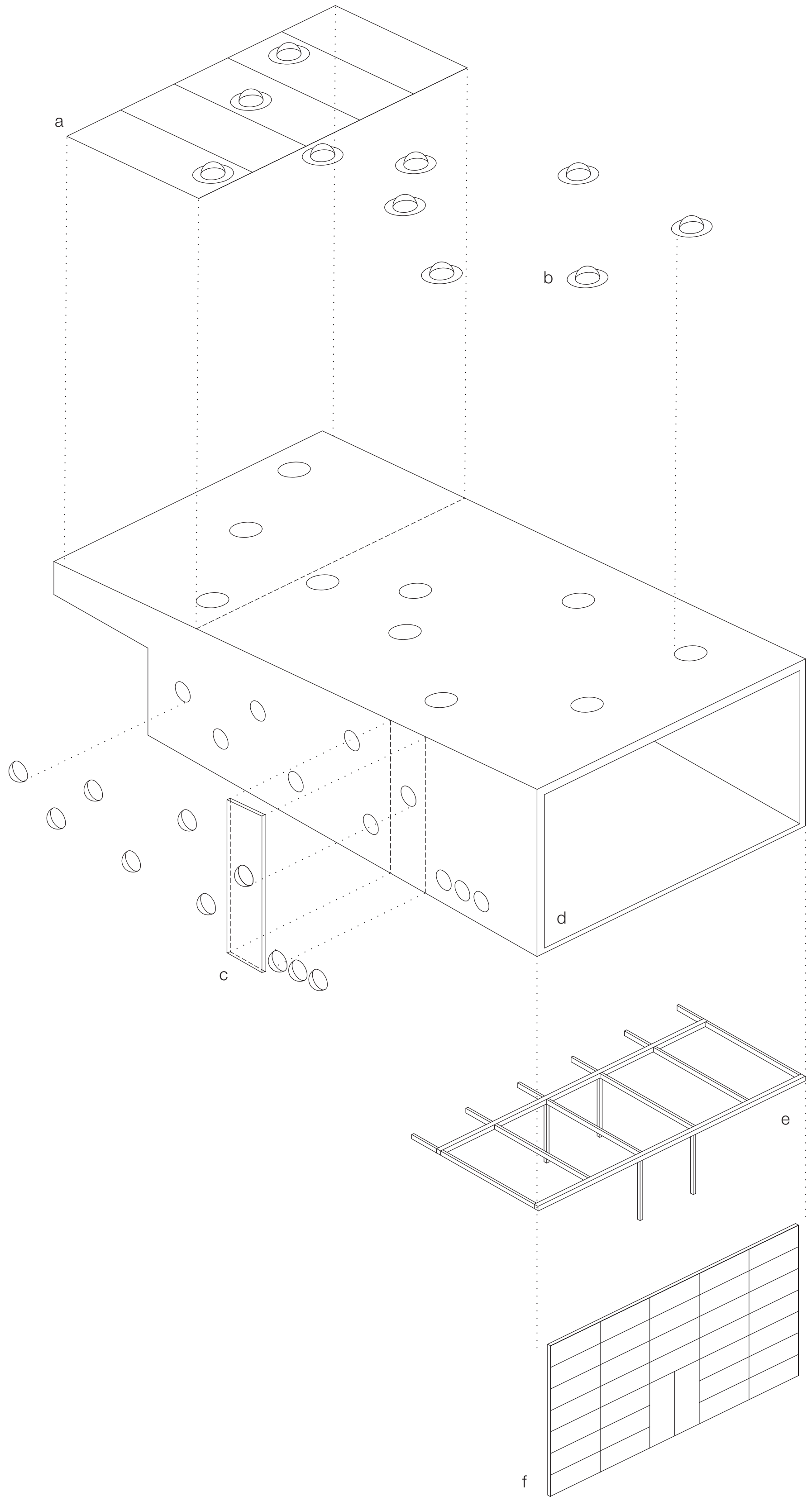
The loadbearing construction is normally divided into primary and secondary structures. In this example the portal frames and the cantilevering canopy constitute the primary structure, while the trapezoidal sheeting forms the secondary structure. The supporting framework for the envelope is frequently attached to the loadbearing structure, and in this case as the trapezoidal sheeting spans unsupported between the main loadbearing members, this is indeed the secondary structure.

The vertical and horizontal loads are carried on the portal frames. Wind girders in the form of X-bracing in the roof and walls transfer the wind loads down to the foundations. Rails at eaves level and struts between the portal frames complete the bracing effect. Owing to their simple fabrication and erection, portal frames are among the most economic types of structure for short to medium spans, and are very popular. However, they are not suitable for every building form.

A ground slab, pad foundations and a peripheral stem wall as protection against frost heave form the foundations, which transfer the loads from the portal frames into the subsoil.



a Pad foundations and stem wall (frost protection)
b Ground slab
c Portal frames (primary structure)
d Canopy framing (primary structure)
e Bracing consisting of eaves rails, struts and wind girder



The enclosing envelope to the shed determines the external appearance. The front facade with the entrance is designed as a huge display window, with the necessary functions incorporated into the design. Whereas the canopy at the rear of the building indicates clearly the loading/unloading zone, the sloping roof is a simple way of creating an effective fall for rainwater and also permits a two-storey arrangement at the front (offices) end. Rainwater is collected in a gutter at the rear end of the roof and drained away via downpipes positioned within the envelope. Lighting, ventilation and smoke/heat dissipation requirements are handled by standard rooflights built into the roof (and the side walls!). Their striking layout can be used by the building owner as a simple advertising motif.
The height of the portal frame primary structure decreases towards the rear of the building. The mezzanine floor is simply suspended between the front two portal frames so that the volume of the building can be reduced.

The vertical walls of the external envelope consist of large-format, lightweight panels, so-called sandwich panels. Such elements enable a shed to be enclosed and thermally insulated quickly, economically and without the need for an elaborate supporting framework.
Uninsulated shed walls generally consist of trapezoidal profile sheeting, corrugated sheets or other profiled sheet metal formats. If condensation has to be avoided internally, insulated steel pans, sandwich elements or an insulated facade construction with an air cavity can be employed. Masonry, autoclaved aerated concrete or timber boards can also be used to construct the walls, with or without insulation.

The roof, the horizontal part of the envelope, is designed as an insulated diaphragm. If designed without a slope, such roofs can also carry rooftop planting, which provides ecological and building performance benefits, but introduces additional loads which have an effect on the construction and hence the costs. Clipped sheet metal coverings or sandwich elements represent economic alternatives. Both require a minimum fall.

a Trapezoidal profile metal sheets
b Rooflights (also in the walls)
c Sandwich panel with rooflight
d Complete envelope
e Framing to mezzanine floor (secondary structure)
f Glass facade

Example A
Section through metal facade, frame

☐ a
The columns and beams of a portal frame are rigidly connected at the corners. The column is normally called a leg, and the beam a cross-beam or rafter. All the internal forces are transferred across this connection. In the case of I-section members, the axial force is carried by the entire cross-section, the shear by the web and the bending by the flanges. In order to accommodate the bending moment in the cross-beam due to the deflection, haunched ends (as shown here) can be incorporated. The haunch increases the lever arm at the end plates and the geometric arrangement of the sections (equal widths) can thus be maintained. In very economic connections, the end plates for transferring the forces frequently extend beyond the actual section itself. This is a pragmatic form of connection but is less convincing in terms of its architecture and requires very careful detailing of the subsequent layers (roof construction, thermal insulation, waterproofing) at this point. Circular holes are cut (flame or laser) in each cross-beam to ease the routing of services through the building.

☐ b
The foundations carry the vertical and horizontal loads transferred from the portal frames. A pocket to accommodate a shear connector and threaded bars are cast into each pad foundation. The shear connector, normally a steel section welded to the underside of the baseplate, resists the horizontal shear. The pre-assembled portal frames are erected, levelled with the help of shims under the baseplates and then bolted down. This arrangement compensates for the inevitable inaccuracies in the concrete foundations. The pocket and the gap beneath the baseplate are then filled with grout. This leg baseplate detail typical of industrial sheds is an economic way of transferring the loads from the portal frame to the foundation. Although this simple connection looks like a fixed base, the thickness and stiffness of the baseplate plus the arrangement of the holding-down bolts determine whether the base has been designed as fixed or pinned. The stem wall to prevent frost heave is a precast concrete component that is placed on the foundation and secured with dowels. It serves as permanent formwork for the edge of the ground slab. In order to avoid interrupting the external finishes, there is a step in each concrete pad foundation on the outside.